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Industrialization, electricity consumption and CO_2 emissions in Bangladesh

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ABSTRACT

This paper investigates the relationship between industrialization, electricity consumption and CO_2 emissions in case of Bangladesh using quarter frequency data over the period of 1975–2010. The ARDL bounds testing approach is applied to examine cointegration in the presence of structural breaks stemming in the series. The causal relationship among the variables is explored by applying the innovative accounting approach (IAA).

Our results indicate that the variables are cointegrated for a long run relationship. We find that financial development adds in energy pollutants. Electricity consumption contributes to CO_2 emissions. Trade openness also has a positive impact on energy pollutants. The results unveil that EKC is existed between industrial development and CO_2 emissions in case of Bangladesh. Our causality analysis shows that electricity consumption Granger causes energy pollutants, industrial growth and financial development. The unidirectional causality exists running from financial development to trade openness and trade openness Granger causes industrial development. This study opens up new insights for policy makers in formulating a comprehensive economic, financial and trade policy to sustain industrialization by improving the environmental quality.

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1. Introduction

In recent years, rapid industrialization, increased population and significant change in pattern of trade and financial sector development, the threat of global warming and climate change is increasing for the last two decades in Bangladesh. The climate change issue is fundamentally important for Bangladesh. The EKC hypothesis explains that the level of carbon emissions is expected

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to rise for many of the economies, contributing further to global warming. The existence of the EKC is a debatable issue and depending on the level of development in the area of industrialization, energy consumption, and pattern of trade with major trading partners might differ significantly in terms of their output-emissions nexus. These fundamentals factors are associated with emissions, which are also closely related to the relations between energy utilization in Bangladesh. In addition, several other factors, e.g. the composition of growth, type of economic activities, the industrialization intensity of foreign trade and financial development influence the emissions-energy-output nexus in Bangladesh.

In Bangladesh a South Asian country, a number of industrial plants were established in different areas (Dhaka, Chittagong, Narangong, Gazipur, etc.) of the country following the both trade and financial liberalization in the 1990s; however, environmental issues were not considered seriously at that time. Thus, the natural environment has been continuously degrading due to industrial enterprises′ unsustainable practices (raw leather processing and chemical wastage and deforestation due to urbanization). According to the World Bank [1] information for Bangladesh, it has emitted about one tenth of the world′s CO_2 emissions in 2006, despite the fact that its 160 million people represent about 2.4% of the world's population. The recent threat in climate change for economic development strategies in many developing or newly industrialized countries in particular for poor industrialization. Previous research study by, Rahman′s [2] revealed that many people are being affected by the resultant industrial pollution in Bangladesh. Another study on the similar sector explains the national pollution profile also shows that industrial sub-sectors contribute to a large percentage of the pollution load in the country [3]. Considering the information reported by Bala and Yusuf [4], suggested that Bangladesh′s existing industrial concerns, which are responsible for environmental pollution and public health hazards, must take appropriate measures for preventing its pollution.

In this study, we contribute the causal relationship between industrialization, electricity consumption and energy pollutants in case of Bangladesh using quarter frequency data over the period of 1975–2010. The intensity in carbon emissions, the demand for electricity consumption and rapid industrialization have raised some questions in Bangladesh′s perspective such as (1) Is there any long-term and short-run relationship between these variables in Bangladesh? (2) What are the policy implications of the findings for Bangladesh and other′s developing or newly industrialized economics? In addition, we also consider the influence of trade and finance within the emissions-energy-industrialization nexus. The methodological discussion is based on the application of the ARDL bounds testing approach in the presence of structural breaks. These methods are performing better to other, especially when the sample size is small. In addition, the causal relationship between the variables is explored by applying the innovative accounting approach (IAA). Due to our imperfect knowledge, this study may be a comprehensive effort on this topic for the economy of Bangladesh and it has five ways contribution to the energy literature by applying: (i) Zivot–Andrews [5] structural break unit root test; (ii) the ARDL bounds testing approach to cointegration for long run relationship between the variables in the presence of structural breaks; (iii) OLS and ECM for long run and short run impacts; (iv) the VECM Granger causality approach for causal relationship; and (v) innovative accounting approach (IAA) to test the robustness of causality analysis. The main empirical findings of this study found that a long run relation exists among the variables. The interesting finding is that the EKC is existed between industrial development and CO_2 emissions in Bangladesh.

The remainder of this paper is structured as follows: section 2 explains literature review. In Section 3, we outline the econometric specification and estimation methodology and discuss how various hypotheses are tested, while Section 4 provides a discussion of our empirical results. Finally, Section 5 discusses major findings and concludes the paper.

2. Literature review

Research strands in the earlier empirical literature to examine the relations between economic growth, energy utilization and emissions [6]. The previous research on energy economics mainly concentrated on testing of the existence of environmental Kuznets curve (EKC). In this context, the pioneering study of Kuznets [7] which claimed for an inverted U-shaped relationship between economic growth and income inequality has been later reformulated to test similar inverted-U relationship between economic growth/income and environmental quality.[2] The results of such research are however contradictory and in many cases researchers failed to establish the inverted-U relationship.[3]

The second argument of the empirical evidence looks at the attention between energy consumption and output suggesting that energy consumption and income may be jointly determined. Following the seminal work of Kraft and Kraft [29]; several others including Masih and Masih [30], Yang [31], Wolde-Rufael [32], Narayan and Singh [33], Narayan et al.[34] tested the energy consumption and economic growth nexus with a variety of econometrics techniques and for different panel of countries. The existing studies on energy-output nexus fall into four broad categories: For instance, studies that find no causality between energy consumption and income in case of a U.S. include those by Akarca and Long [35], Yu and Hwang [36], Yu and Jin [37], Stern [38], and Cheng [39]. Fatai et al. [40] find no causality between these variables in New Zealand. The same result is true in the UK [41] and France [42]. In contrast, the results of both bidirectional and unidirectional causality are prevalent particularly in developing nations and numerous studies have found such bidirectional causality with real life data.[4] Studies find two-way causation in South Korea include those of Masih and Masih [30], Glasure [43] and Oh and Lee [44]. A similar causation for the Philippines and Thailand is found by Asafu-Adjaye [45]. Unidirectional causation from output to energy consumption is found in different countries.[5] A number of studies have found the direction of causality from energy consumption to output growth.[6]

Previous researchers have attention not only at income or economic development variables but also extended their analysis to include other aspects such as financial development or trade openness or trade intensity or industry value-added of a country. These factors are important for industrialized countries like Bangladesh. The relations between carbon emissions and trade

[2] For example, Grossman and Krueger [8], Shafik [9], Dinda and Coondoo [10], Heil and Selden [11], and Friedl and Getzner [12] attempted to test the existence of EKC for different countries.

[3] The studies such as Ang [13] for France; Ang [14] and Saboori et al.[15] in Malaysia; Dhakal [16], Tiwari [17], and Tiwari et al.[18] in India; Shiyi [19], Jalil and Mahmud [20], and Zhang and Cheng [21] for China; Akbostanci et al.[22] and Ozturk et al.[23] in Turkey; Lean and Smyth [24] for ASEAN countries; Narayan and Narayan [25] for 43 developing countries, Fodha and Zaghdoud [26] for Tunisia, Nasir and Rehman [27] and Shahbaz et al. [28(a)] in Pakistan; Shahbaz et al. [63] for Romania and, Shahbaz and Leitão [91] for Portugal noted the empirical evidence of the EKC.

[4] Some of the studies in this context are the work of Shahbaz and Lean [92] and Shahbaz et al.[28(b)] for Pakistan; Soytas and Sari [49] for Argentina; Ghali and El-Sakka [93] for Canada; Zachariadis and Pashourtidou [94] for Cyprus; Hondroyiannis et al. [95] for Greece; Jumbe [96] for Malawi; Masih and Masih [52] for Pakistan, etc.

[5] Like Australia [46], India [47], Singapore [48,49], and Taiwan [50].

[6] These studies include those for China [51], Fiji [33], India [52], Indonesia [45], Philippines [41], Sri Lanka [53], Taiwan [31], Turkey [49,[54], Venezuela [55], Tunisia [56], and Pakistan [57].

consider fact that developed economies would specialize in human or physical capital intensive activities which are less emissions more intensive than developing countries. Trade therefore may result in increased pollution in developing countries due to increased industrialization of these emission intensive goods in these countries. The study of Grossman and Krueger [8] is pioneering effort in this regard while similar research question has also been addressed by Lucas et al. [58], Wyckoff and Roop [59], Nohman and Antrobus [60], etc. The earlier findings fail to conclude the conclusive evidence of the relationships between trade and environmental quality. Applying Turkish data, Halicioglu [61] estimates the causal relationship between trade, CO_2 emission, and income and energy consumption and found that income is the most crucial determinant of carbon emissions, followed by energy consumption and finally trade. Using the similar approach, the importance of foreign trade in determining the level of CO_2 emissions has also been emphasized by Anderson et al. [62]. In their analysis, the authors find that the exports of China played an important role in generating emissions in the transport sector which is greater than the emissions attributable to imports. Recent study by Shahbaz et al. [28(b)] also found that trade openness increases CO_2 emissions due to poor implementation of environmental regulation in case of Pakistan. Furthermore, financial instability is also positively linked with environmental degradation [63].

Applying augmented vector autoregression (VAR) approach of the Toda and Yamamoto [64] after incorporating gross fixed capital formation and labor force into the model, Soytas et al. [6] investigated energy consumption, output and carbon emissions nexus for the USA and found no causal relationship between income and carbon emissions or between energy use and income. Using the similar procedure, Zhang and Cheng [21] investigated the energy consumption, output and carbon emissions nexus for China, controlling for capital and urban population. The authors found unidirectional long-run causality running from GDP to energy consumption and from energy consumption to carbon emissions. Considering the study by Sari and Soytas [65], investigated the relationship between carbon emissions, income, energy and total employment in five OPEC countries, the authors found that none of the following countries namely Algeria, Indonesia, Nigeria, Saudi Arabia and Venezuela need to sacrifice economic growth in order to reduce CO_2 emissions. Applying the ARDL cointegration approach; Halicioglu [61] examined the cointegration in a log linear quadratic relationship between per capita CO_2 emissions, per capita energy use, per capita real income, square of per capita real income and openness ratio, and reported that there is a short-and-long runs bidirectional causality between carbon emissions and income in Turkey. In a similar study; Jalil and Mahmud [20] found unidirectional causality from economic growth to CO_2 emissions in China. The study also indicates that carbon emissions are mainly determined by income and energy consumption in the long-run. Trade has a positive but statistically insignificant impact on CO_2 emissions.

Using variables like stock market value added, foreign direct investment, deposit money bank assets, capital account convertibility, financial liberalization, financial openness etc, in order to capture the level of financial development, Tamazian et al. [66] conducted detailed analysis on the relationship between financial development and environmental degradation. Over time the research on environment-development nexus has not only extended and modified in terms of the research questions addressed, but also has developed from the viewpoint of methodology and econometric modeling techniques. Most of the studies like that of Peng and Sun [67] and Akbostanci et al. [22] have applied cointegration technique and Granger causality method to understand the nexus. In terms of the findings of these analyses, no clear cut conclusion can be made and results differ depending upon the variables used and countries considered. In case of ASEAN countries, a recent study conducted by Lean and Smyth [24] with panel data attempted to examine the long-run relationship between CO_2 emission, electricity consumption and output as well as the causal relationship between these variables. Their analysis revealed that there is short-run panel Granger causality from carbon emissions to electricity consumption and long-run unidirectional causality from electricity consumption and CO_2 emissions to GDP. Akbostanci et al. [22] also found pollution and income variables being cointegrated.

Previous study on Bangladesh′s energy and output by Mozumder and Marathe [68], over the 1971–1999 period, found that per capita GDP causes per capita electricity consumption, but the reverse is not true. However, small sample size is the limitation of this study. From the annual data from 1971 to 2007, Uddin et al. [69] investigated the inter-temporal causal relationship between energy consumption and economic growth in Bangladesh and unidirectional causality runs from energy consumption to economic growth in Bangladesh and then restrictions on the use of energy could lead to a reduction in economic growth. The limitation of this approach is bivariate framework to investigate the relationship between energy and income. A study in Bangladesh by Paul and Uddin [70] examined energy-output dynamics for Bangladesh and found that while fluctuations in energy consumption do not affect output fluctuations, movements in output inversely affect movements in energy use. The results of Granger causality tests in this respect are consistent with those of innovative accounting that includes variance decompositions approach and impulse responses. Autoregressive distributed lag models also suggest a role of output in Bangladesh′s energy use. However, Paul and Uddin study does not consider the effect of openness, finance and industrialization impact in their assigned model specification. Our study filled this gap. Working with annual data, Ahamad and Islam [71] examine the causal relationship between per capita electricity consumption and per capita GDP of Bangladesh using the vector error correction specified Granger causality for the period of 1971–2008. Empirical findings reveal that there is short-run unidirectional causal flow running from per capita electricity consumption to per capita GDP without feedback. Structural break was absent in their estimation process which is valid for Bangladesh energy output dynamics [70]. Ahiduzzaman and Islam [72] study presents a review of the potential and utilization of the renewable energy sources in Bangladesh. In case of Bangladesh, Alam et al. [73] investigated the relationship between energy consumption, CO_2 emissions and economic growth by applying Johansen and Juselius [74], cointegration and the VECM Granger causality approaches. Their results noted that energy consumption Granger causes economic growth and CO_2 emissions. Furthermore, economic growth is Granger cause of CO_2 emissions. Amin et al. [75], however, found a neutral effect between CO_2 emissions and economic growth. Both of these earlier papers have shortcomings in the methodological framework that structural break is not considered in their dynamics estimation which is filled up in this current study. Recent studies, the top-ten environment polluting industries in Bangladesh; these are the tannery, pulp and paper, fertilizer, textile and cement industries, Hoque and Clark [76] using both primary and secondary data from each industry group, two sample plants were selected with five executives participating from each plant. This study highlights the reality of Bangladeshi industrial plants in applying pollution prevention initiatives. It reveals that compared to leading firms in developed countries, pollution prevention initiatives in Bangladesh are considerably underutilized.

3. Data construction and methodology

3.1. Data construction

The data used for the analysis has mainly been taken from World Development Indicator (CD-ROM, 2012), published by the World Bank. It covers the period of 1975–2010. The variables under consideration are carbon emissions, industrial value-added as a share of GDP, electricity consumption, domestic credit to private sector as a share of GDP and trade openness (exports+imports) as a share of GDP. For our analysis these variables have been converted to logarithmic form. Here, carbon emissions is measured in per capita, electricity use is calculated as Electric power consumption (kWh) per capita, industrial value added measure in real per capita, financial development is measured in domestic credit to the private sector per capita in real terms. As a proxy for foreign trade, trade openness is calculated as the sum of real export and imports per capita has been used. Thus, we get 140 observations on each series ranging from 1975 to 2010, the longest possible joint dataset on Bangladesh. We have converted all the annual series into quarterly data to avoid the problem of degree of freedom and efficient empirical results. We used quadratic match sum method to transform all the variables into quarter frequency following Romero [77] and McDermott and McMenamin [78].[7]

3.2. Zivot–Andrews unit root test logarithm

Zivot–Andrews [5] developed a unit root test in the presence of structural break in the econometric models. The model is applicable in the context of macroeconomic series. The model constructed at the three different forms such as level, function and both in trend and intercept function of the variables to be applied in the time series analysis.

3.3. The ARDL bounds testing approach to cointegration

The empirical analysis of this study employs the ARDL bounds testing approach [79, 80] to explore the existence of long-run equilibrium relations among the variables. This approach has number of advantages compared to other traditional cointegration techniques. First, it allows for smaller sample sizes. Second, it can be used regardless of whether the variables are purely I (0), purely I (1), or mutually cointegrated. Third, it provides unbiased long-run estimates and valid t-statistics. Finally, this approach provides a method of assessing short-run and long-run. Moreover, a dynamic unrestricted error correction model (UECM) can be derived through a simple linear transformation. The UECM integrates the short-run dynamics with the long-run equilibrium without losing any long-run information. The UECM is specified as follows:

$$\begin{aligned}\Delta \ln C_t = {} & \alpha_1+\alpha_{DUM}DUM+\alpha_C \ln C_{t-1}+\alpha_I \ln I_{t-1}+\alpha_E \ln E_{t-1} \\ & +\alpha_F \ln F_{t-1}+\alpha_O \ln O_{t-1}+\sum_{i=1}^{p}\alpha_i\Delta \ln C_{t-i} \\ & +\sum_{j=0}^{q}\alpha_j\Delta \ln I_{t-j}+\sum_{k=0}^{r}\alpha_k\Delta \ln E_{t-k}+\sum_{l=0}^{s}\alpha_l\Delta \ln F_{t-l} \\ & +\sum_{m=0}^{t}\alpha_m\Delta \ln O_{t-m}+\mu_t \qquad (1)\end{aligned}$$

where $\ln C_t$ = natural log of CO_2 emissions per capita; $\ln I_t$ = natural log of real industrial value-added per capita; $\ln E_t$ = natural log of electricity consumption per capita; $\ln F_t$ = natural log of real domestic credit to private sector per capita; $\ln O_t$ = natural log of real trade openness (exports+imports) per capita and DUM is dummy variable to capture structural break based on Z–A unit root test. Δ is the first difference operator, T is the time trend and μ_t is the error term. The optimal lag structure of the first difference regression is selected based on Akaike Information Criteria (AIC). The F-test is used in bounds test for the existence of the long-run relationship [80] and it tests for the joint significance of lagged level variables involved. The null hypothesis of the non-existence of a long-run relationship for the equation of being $H_0: \alpha_C=\alpha_I=\alpha_E=\alpha_F=\alpha_O=0$ against the alternative hypothesis $H_a: \alpha_C\neq\alpha_I\neq\alpha_E\neq\alpha_F\neq\alpha_O\neq0$. According to the ARDL approach, if the F-statistic exceeds the upper critical value, we conclude in the favor of long run relationship. If the F-statistic falls below the lower critical value, we cannot reject the null hypothesis of no cointegration. However, if the F-statistic lies between the two bounds, inference is inconclusive.[8]

3.4. Innovative accounting approach for Granger causality

According to the Shahbaz et al. [28] the Granger causality test is unable to indicate how much feedback exists from one variable to the other. Due to the limitation of the Granger causality test, we include innovative accounting approach (IAA) to investigate the dynamic causal relationships among carbon emissions, electricity consumption and industrialization, financial development and trade openness. The uniqueness of the IAA is that it avoids the problem of endogeneity and integration of the series. This approach has an advantage compared to the VECM Granger causality test because the latter only shows a causal relationship between the variables within the sample period while the former illustrates the extent of causal relationship ahead the selected sample period. The IAA includes variance decomposition method and impulse response function. This procedure decomposes forecast error variance for each series following a standard deviation shock to a specific variable and enables us to test which series is strongly impacted and vice versa.

For instance, if a shock in CO_2 emissions has significant effects of industrialization but a shock occurring in industrialization only affect very minimum the variations of CO_2 emissions. Then, this is inferred as a unidirectional causality runs from CO_2 emissions to industrialization. If the industrialization explains more of the forecast error variance of CO_2 emissions; then we deduce that industrialization causes CO_2 emissions. The bidirectional causality exists when shocks in CO_2 emissions and industrialization have a strong impact on the variability of CO_2 emissions and industrialization respectively. If shocks occur in both series do not have any impact on the industrialization and CO_2 emissions then there is no causality between the variables.

Impulse response function helps us to trace out the time path of the impacts of shocks of variables in the VAR. One can determine how much CO_2 emissions responses due to its own shock and shock in industrialization. We support the hypothesis that industrialization causes CO_2 emissions of the impulse response function indicates significant response of CO_2 emissions to shocks in industrialization than other variables. A strong and significant reaction of CO_2 emissions to shocks in industrialization implies that CO_2 emissions cause industrialization. This study incorporates CO_2 emissions, industrialization, electricity consumption, financial development and trade openness to examine the relationship between CO_2 emissions and its determinants in the

[7] All the series are transformed into natural-log form. The log-linear specification of the series provides efficient and consistent empirical results compared to simple specification. Furthermore, transformation of series into natural log reduces the sharpness of the data and provides reliable empirical findings.

[8] In addition, Pesaran et al.[80] caution that critical values for the bound test are sensitive to the number of regressors (k) in the model, and Narayan[81] argues that critical values of F-test depend on sample size.

VAR model. A VAR system takes the following form [82]:

$$V_t = \sum_{i=1}^{k} \delta_i V_{t-i} + \eta_t \tag{2}$$

where

$$V_t = (C_t, I_t, E_t, F_t, O_t)$$

$$\eta_t = (\eta_C, \eta_I, \eta_E, \eta_F, \eta_O)$$

δ_i are the estimated coefficients and η is a vector of error terms.

4. Results and discussions

Descriptive statistics and correlation matrix is presented in Table 1. Based on Jarque–Beratest statistics, our results indicate that all the series are normally distributed having zero mean while variance is constant. This implies that we should peruse for further analysis. The correlation matrix reveals a positive association between the underlying variables. For instance, industrialization is positively linked to CO_2 emissions and same finding is for electricity consumption and CO_2 emissions. A positive correlation is found of financial development and trade openness with CO_2 emissions. Electricity consumption, financial development and trade openness are positively related with industrialization. A positive correlation of financial development and trade openness is found with electricity consumption. There is a positive correlation between financial development and trade openness.

There are numerous unit root tests available to test stationarity properties of time series data. These unit root tests are ADF, PP, DF-GLS, KPSS and Ng-Perron. Generally, these unit root tests are not reliable in the presence of structural break [83]. This limitation of classical unit root tests such as ADF, PP, DF-GLS and KPSS has been covered by applying Zivot–Andrews [5] structural break unit root test. Zivot–Andrews unit root test contains information about one unknown structural break in the series. The results of Zivot and Andrew [5] unit root test are presented in Table 2. This empirical evidence indicates that the series is non-stationary at level but found to be stationary at 1st difference. This implies that all the series are integrated at I(1).

According to the ARDL approach, lag order of the variables is important for the model specification. Table 3 indicates the lag length criterion. In this paper, we followed Akaike information criterion to select an appropriate lag length. It is pointed by Lütkepohl [84] that AIC has superior power properties for small sample data compared to any lag length criterion. Akaike information criterion provides efficient and consistent results as compared to final prediction error (FPE), Schwarz information criterion (SBC) and Hannan–Quinn information criterion (HQ). Based on the empirical evidence provided by AIC, we find that the optimum lag is 6 in. such quarter frequency data over the period of 1975–2010 in case of Bangladesh.

Table 1
Descriptive statistics and correlation matrix.

Variables	$\ln C_t$	$\ln I_t$	$\ln E_t$	$\ln F_t$	$\ln O_t$
Mean	−1.9418	7.8960	4.0189	4.3215	8.0852
Std. Dev.	0.4897	0.4643	0.8585	0.5115	0.6062
Jarque–Bera	2.4773	2.2765	2.0711	1.1488	2.3841
Probability	0.2897	0.3203	0.3550	0.5630	0.3035
$\ln C_t$	1.0000				
$\ln I_t$	0.9832	1.0000			
$\ln E_t$	0.9898	0.9915	1.0000		
$\ln F_t$	0.9845	0.9746	0.9793	1.0000	
$\ln O_t$	0.9261	0.9599	0.9341	0.9221	1.0000

Table 2
Z–A unit root analysis

Variable	Level			1st Difference		
	T-statistic	Time break	Decision	T-statistic	Time break	Decision
$\ln C_t$	−4.644 (2)	1994Q1	Unit root	−10.513 (3)*	1984Q1	Stationary
$\ln I_t$	−4.940 (3)	1979Q3	Unit root	−15.552 (3)*	1978Q4	Stationary
$\ln I_t^2$	−4.449 (3)	1979Q3	Unit root	15.422 (4)*	1978Q4	Stationary
$\ln E_t$	−4.420 (2)	2004Q2	Unit root	−9.120 (3)*	1980Q3	Stationary
$\ln F_t$	−4.481 (2)	1989Q2	Unit root	−7.134 (4)*	1979Q4	Stationary
$\ln O_t$	−4.142 (3)	1985Q2	Unit root	9.413 (5)*	1984Q2	Stationary

* Significant at 1% level of significance. Lag order is shown in parenthesis.

Table 3
Lag order selection criteria.

VAR lag order selection criteria						
Lag	Log *L*	LR	FPE	AIC	SC	HQ
0	1760.621	NA	2.51e−19	−25.80325	−25.67475	−25.75103
1	3399.985	3109.969	1.44e−29	−49.38213	−48.48263	−49.01659
2	3552.110	275.1679	2.62e−30	−51.08985	−49.41936	−50.41101
3	3567.684	26.79737	3.57e−30	−50.78948	−48.34799	−49.79732
4	3578.486	17.63231	5.24e−30	−50.41892	−47.20643	−49.11344
5	3782.955	315.7243	4.51e−31	−52.89640	−48.91292	−51.27762
6	3937.214	224.5824*	8.20e−32*	−54.63550*	−49.88102*	−52.70340*
7	3957.061	27.14392	1.09e−31	−54.39796	−48.87248	−52.15254
8	3970.924	17.73600	1.62e−31	−54.07241	−47.77593	−51.51368

Note: LR, sequential modified LR test statistic (each test at 5% level); FPE, final prediction error; AIC, Akaike information criterion; SC, Schwarz information criterion; HQ, Hannan–Quinn information criterion.

* Lag order selected by the criterion.

Table 4
ARDL cointegration analysais

Variable	$\ln C_t$	$\ln I_t$	$\ln I_t^2$	$\ln E_t$	$\ln F_t$	$\ln TR_t$
Structural break	1994Q1	1979Q3	1979Q3	2004Q2	1989Q2	1985Q2
F-statistics	5.202*	3.372***	3.805***	4.740**	2.460	6.487*
Critical values[a]	1 % level	5 % level	10 % level			
Lower bounds	3.60	2.87	2.53			
Upper bounds	4.90	4.00	3.59			
Diagnostic test						
R^2	0.6720	0.9847	0.9845	0.7650	0.8356	0.9116
$Adj-R^2$	0.3440	0.9757	0.9754	0.6269	0.7389	0.8516
F-statistic	3.0498**	11.1130*	12.5765*	5.5369*	8.6434*	11.5461*

* Significant at 1%.
** Significant at 5%.
*** Significant at 10%.level.
[a] Critical values bounds are from [81] with unrestricted intercept and unrestricted trend.

In this section we present the empirical findings based on our methodology discussed in the last section. The estimation results for cointegration are presented in Table 4. The uniqueness of this paper is that the structural break incorporated into the ARDL equation while computing *F*-statistics. If the calculated *F*-statistic exceeds the upper bound, then null hypothesis of no cointegration among variables in $\ln C_t$ can be rejected. If the calculated *F*-statistic falls below the lower bound, the null hypothesis of no long-run relationship cannot be rejected (see footnote 3). The results reported in Table 4 show that there is evidence of cointegration when $\ln I_t$ and $\ln E_t$ $(\ln O_t)$ are taken as dependent variables in the presence of structural break at 1%, 10% and 5% (1%) except $\ln F_t$ in the model in case for Bangladesh. This shows that there are five cointegrating vectors validating the existence of long run relationship between the variables in presence of structural break stemming in the series of CO_2 emissions, industrialization, electricity consumption, financial development and trade openness. The structural breaks in 1994Q1, 1979Q3, 2004Q2, 1989Q2 and 1985Q2 reveal that Bangladesh economy underwent the structural adjustment policies in the early 1980s. This includes institutional as well as policy level alterations. The financial and external sectors underwent substantial reforms in the mid 1980s and early 1990s that are likely to have influenced real output. The real output is also likely to have structural breaks as a consequence of these reforms. In the past decade or so, Bangladesh economy's growth hovered around 5–6% per annum. From the restoration of parliamentary democracy in the 1990 and onwards, it has been observed that the periodic growth averages are much higher than the previous two decades. GDP growth has been much more volatile till 1990, which became much more stable and increasing in the subsequent years.

The marginal impacts of industrialization, electricity consumption, financial development and trade openness on CO_2 emissions are reported in Table 5. The results indicated that all the coefficients are according to our expectations. We find that there is an inverted U-shaped relationship found between industrialization and carbon emissions. The linear and squared terms of industrialization have positive and negative relationships with carbon emissions. We note that a 1% rise in real industrial value added per capita will raise CO_2 emissions by 4.0646% while a negative sign of the squared term of real industrial value added per capita seems to document the declining of energy emissions and real industrial value added per capita at the higher level of income is -0.2434% at the 1% level of significance. These evidences support the EKC hypothesis revealing that carbon emissions increase in the initial stage of industrialization and start to decline once industrial development is completed.

Table 5
Long run regression analysis

Dependent variable $\ln C_t$			
Variable	Coefficient	Std. Error	*t*-Statistic
Constant	-5.3609*	0.6162	-8.6988
$\ln I_t$	4.0646*	0.5883	6.9087
$\ln I_t^2$	-0.2434*	0.0320	-7.5881
$\ln F_t$	0.1527*	0.0550	2.7752
$\ln E_t$	0.3127*	0.0612	5.1076
$\ln O_t$	0.0893*	0.0307	2.9089
R^2	0.9895	$Adj-R^2$	0.9891
F-statistic	26.0365*		
Diagnostic test	*F*-statistic	*P*-value	
$\chi^2 NORMAL$	0.5147	0.4624	
$\chi^2 SERIAL$	0.4347	0.5000	
$\chi^2 ARCH$	0.3111	0.7787	
$\chi^2 WHITE$	0.9534	0.3230	
$\chi^2 REMSAY$	0.1680	0.8835	

Note: x^2 *NORMAL* is for normality test, x^2 *SERIAL* for LM serial correlation test, x^2 *ARCH* for autoregressive conditional heteroskedasticity, x^2 *WHITE* for white heteroskedasticity and x^2 *REMSAY* for Resay Reset test.

* The significant at 1% level.

The impact of electricity consumption of CO_2 emissions is positive and significant at 1% significance level. We infer that all else is same, a 1% rise in electricity consumption is linked with a 0.3127% increase in CO_2 emissions. To develop low-carbon society in Bangladesh, a package of plans of Bangladesh, 2010–2021 such as National Energy policy, National Renewable Energy policy and Strategic Transportation Plans was introduced. These policies are emphasized on fuel switch, introduction of renewable and nuclear energy in power sector, improvise the energy efficient equipment, increment of public transport and improve traffic management system. Realization and implementation of such policy package for low-carbon society development requires necessary information on changes in socioeconomic parameters, energy demand, CO_2 emissions and emissions reduction in future. This report will provide essential information on socioeconomic parameters and potential low-carbon measures in making policy plan for Bangladesh.

Financial development and CO_2 emissions are positively linked and statistically significant at the 1% level of significance. It is noted that a 0.15275% increase in CO_2 emissions will be increased by 1% rise in financial development. Reforms in the financial sector in Bangladesh started in the early 1980s and gained the pace in the 1990s. The main focus of these reforms was to improve the process of financial intermediation by taking up a series of measures related to legal,

policy and institutional restructuring. The first phase of reforms in 1980s includes denationalization of public banks in 1984, allowing new private banks in 1986, establishment of a National Commission on Money, Banking and Credit to identify problems in the banking sectors and prescribe policies as remedial measures. In the later phase of reforms, the government allowed for market-determined deposits and lending rates. Other measures include the introduction of indirect monetary instruments to replace direct credit control, improvement of the capital base of commercial banks, and reforms in the legal framework of debt recovery [85]. In 1997, the ADB approved a program loan of $80 million that was aimed at enhancing market capacity, and developing a fair, transparent, and efficient capital market [86]. This implies that environmental quality was and is not on the priority by the financial sector in Bangladesh.

Trade openness has positive and statistically significant impact on CO_2 emissions. Keeping other economic agents constant, a 1% increase in trade openness increases CO_2 emissions by 0.0893%. By the end of the 1970s, Bangladesh partially changed its anti-exports bias policies and by the mid-1980s it undertook policies and programs that resulted in consistent improvement in the incentive to export. By the 1990s Bangladesh became more exports oriented and significant improvements have been made in exports policy and administration. During the first half of the decade, liberalization policy taken by the governments for swelling imports gave support to the flow of inputs for exports-oriented and domestic industries, and led to a surge in consumer and non-production related imports [87]. This shows that Bangladesh followed exports-oriented policies at the cost of environment.

Log run model fulfills the assumptions of the classical linear regression model (CLRM) such as normality of the error term, serial correlation, autoregressive conditional heteroskedasticity as well as white heteroskedasticity. Our results find that residual term shows normal distribution and evidence of no serial correlation is found. The autoregressive conditional heteroskedasticity and white heteroskedasticity are not found. Finally, the short run model is well specified as confirmed by Ramsey RESET tests.

The short run results are illustrated in Table 6. The results find that linear and nonlinear terms of industrial value-added per capita have positive and negative signs (inverted-U shaped relation) on CO_2 emissions but both are statistically insignificant. The impact of financial development is positive on CO_2 emissions and it is statistically significant at 10% significance level. Electricity consumption is inversely linked with CO_2 emissions at 5% level of significance. Trade openness increases CO_2 emissions at 5% level of significance. The statistically significant estimate of lagged error term i.e. ECM_{t-1} with negative sign corroborates our established long run relationship between carbon emissions, industrialization, electricity consumption, financial development and trade openness. The lagged error-correction term is negative and statistically significant. This implies that short run deviations from short run towards long run are corrected by 8.61% in each quarter and it would take almost four years to reach the stable log run equilibrium path in CO_2 emissions model in case of Bangladesh.

The results of diagnostic tests suggest that the short run model passes all tests successfully such as autoregressive conditional heteroskedasticity, white heteroskedasticity and specification in the model. This indicates that there is no problem of autoregressive conditional heteroskedasticity. The variance is homoscedastic and functional form of the short run model is well organized. The empirical finding shows that short run empirical evidence is consistent and stable for policy purpose regarding carbon emissions in case of Bangladesh.

The stability of the ARDL bounds testing estimates is investigated by applying the CUSUM and CUSUMsq tests. The results are shown in Figs. 1 and 2. The plots of the CUSUM statistics are well within the critical bounds.

The plots of the CUSUM of squares statistics are not well within the critical bounds. Furthermore, we apply Chow forecast test to examine the significance of structural breaks in an economy for the period 1993–2005 (explanations are given above). In this study, F-statistics computed in Table 7 suggests that there is no

Table 6
Short run regression analysis

Dependent variable: ln C_t			
Variable	Coefficient	Std. error	t-Statistic
Constant	0.0029*	0.0006	4.2912
ln I_t	0.3083	1.8149	0.1698
ln I_t^2	−0.0235	0.1201	−0.1962
ln F_t	0.1265***	0.0760	1.6629
ln E_t	−0.1595**	0.0673	−2.3696
ln O_t	0.1023**	0.0403	2.5342
ECM_{t-1}	−0.0861*	0.0315	−2.7310
R^2	0.1695	$Adj-R^2$	0.1321
F-statistic	4.5258*		
Diagnostic tests			
Test	F-statistic	Prob. value	
$\chi^2 NORMAL$	0.1431	0.8800	
$\chi^2 SERIAL$	0.2124	0.8677	
$\chi^2 ARCH$	0.0485	0.8856	
$\chi^2 WHITE$	0.2996	0.6014	
$\chi^2 REMSAY$	2.9919	0.1162	

Note: x^2 NORMAL is for normality test, x^2 SERIAL for LM serial correlation test, x^2 ARCH for autoregressive conditional heteroskedasticity, x^2 WHITE for white heteroskedasticity and x^2 REMSAY for Resay Reset test.

* The significant at 1%.
** The significant at 5%.
*** The significant at 10% levels.

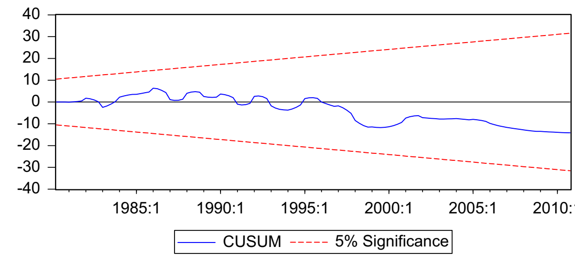

Fig. 1. Plot of cumulative sum of recursive residuals.

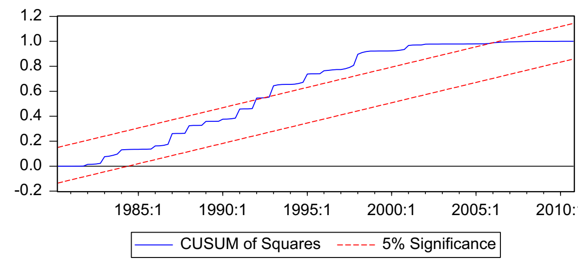

Fig. 2. Plot of cumulative sum of squares of recursive residuals.

Table 7
Chow forecast test

Chow forecast test: Forecast from 1993Q1 to 2010Q4			
F-statistic	0.6843	Probability	0.9389
Log likelihood ratio	82.889	Probability	0.1787

Table 8
Variance decomposition method

Period	$\ln C_t$	$\ln I_t$	$\ln E_t$	$\ln F_t$	$\ln O_t$
Variance decomposition of $\ln C_t$					
1	100.0000	0.0000	0.0000	0.0000	0.0000
2	99.5455	0.1750	0.0153	0.2230	0.0409
3	98.5077	0.5697	0.0227	0.6972	0.2025
4	96.7884	1.1948	0.0866	1.3590	0.5710
5	94.4321	1.9645	0.3087	2.1327	1.1617
6	91.5015	2.7499	0.8520	2.9624	1.9341
7	88.0636	3.4399	1.8918	3.8088	2.7956
8	84.1943	3.9708	3.5510	4.6476	3.6362
9	80.0078	4.3296	5.8356	5.4635	4.3635
10	75.6685	4.5409	8.6151	6.2481	4.9271
11	71.3684	4.6474	11.661	7.0006	5.3223
12	67.2851	4.6936	14.7218	7.7233	5.5760
13	63.5489	4.7164	17.5885	8.4185	5.7275
14	60.2324	4.7414	20.1275	9.0845	5.8140
15	57.3570	4.7834	22.2807	9.7155	5.8632
16	54.9070	4.8482	24.0492	10.3025	5.8929
17	52.8427	4.9356	25.4724	10.8364	5.9126
18	51.1109	5.0412	26.6103	11.3108	5.9266
19	49.6526	5.1592	27.5292	11.7236	5.9356
20	48.4100	5.2837	28.2924	12.0744	5.9392
Variance decomposition of $\ln I_t$					
1	0.0180	99.9819	0.0000	0.0000	0.0000
2	0.2323	98.4507	0.6372	0.0764	0.6031
3	0.5514	94.4658	2.3904	0.9652	1.6269
4	0.6882	86.0900	6.6907	2.2462	4.2846
5	0.6252	74.1082	13.4492	3.3848	8.4324
6	0.5005	61.2797	21.3213	3.9109	12.987
7	0.3998	50.2847	28.6677	3.9119	16.7357
8	0.3253	42.0615	34.7154	3.6631	19.2345
9	0.2784	36.3654	39.3841	3.3667	20.6052
10	0.2912	32.5830	42.8654	3.1109	21.1493
11	0.4078	30.1260	45.3965	2.9195	21.1499
12	0.6553	28.5328	47.1995	2.7905	20.8217
13	1.0288	27.4722	48.4722	2.7133	20.3133
14	1.4946	26.7220	49.3869	2.6747	19.7216
15	2.0047	26.1430	50.0860	2.6600	19.1060
16	2.5127	25.6543	50.6783	2.6551	18.4994
17	2.9840	25.2126	51.2383	2.6478	17.9171
18	3.4002	24.7968	51.8099	2.6292	17.3637
19	3.7565	24.3984	52.4120	2.5949	16.8380
20	4.0581	24.0154	53.0461	2.5439	16.3363
Variance decomposition of $\ln E_t$					
1	3.9586	1.9912	94.0501	0.0000	0.0000
2	3.2369	2.4101	94.3385	0.0093	0.0049
3	2.9013	2.2918	94.7052	0.0959	0.0055
4	2.3851	2.3525	94.9682	0.2639	0.0300
5	1.8624	2.5721	94.9398	0.5394	0.0860
6	1.5526	2.9444	94.4067	0.9161	0.1799
7	1.6580	3.4358	93.2158	1.3789	0.3112
8	2.2810	4.0012	91.3460	1.8994	0.4721
9	3.3867	4.5902	88.9289	2.4456	0.6484
10	4.8272	5.1588	86.2003	2.9897	0.8238
11	6.4054	5.6780	83.4190	3.5127	0.9848
12	7.9399	6.1340	80.7985	4.0046	1.1227
13	9.3031	6.5251	78.4754	4.4617	1.2345
14	10.4293	6.8558	76.5106	4.8833	1.3209
15	11.3044	7.1336	74.9076	5.2696	1.3846
16	11.9487	7.3667	73.6340	5.6209	1.4295
17	12.4003	7.5631	72.6390	5.9377	1.4597
18	12.7035	7.7303	71.8665	6.2207	1.4788
19	12.9004	7.8753	71.2629	6.4714	1.4898
20	13.0274	8.0039	70.7816	6.6917	1.4952
Variance decomposition of $\ln F_t$					
1	0.0866	20.8889	0.2791	78.7453	0.0000
2	0.7384	15.8874	0.0949	83.2738	0.0053
3	2.0547	12.4193	0.1382	85.3799	0.0077
4	3.5066	9.9519	0.4568	86.0630	0.0214
5	4.8811	8.3185	1.0580	85.7045	0.0376
6	6.0735	7.2921	1.9280	84.6609	0.0453

Table 8 (*continued*)

Period	ln C_t	ln I_t	ln E_t	ln F_t	ln O_t
7	7.0740	6.7030	3.0202	83.1610	0.0414
8	7.9027	6.4277	4.2844	81.3479	0.0370
9	8.5835	6.3730	5.6753	79.3184	0.0495
10	9.1346	6.4627	7.1581	77.1521	0.0922
11	9.5692	6.6334	8.7075	74.9220	0.1677
12	9.8987	6.8362	10.3038	72.6926	0.2685
13	10.1361	7.0379	11.9297	70.5148	0.3812
14	10.2967	7.2200	13.5670	68.4239	0.4922
15	10.3976	7.3753	15.1961	66.4397	0.5911
16	10.4563	7.5043	16.7956	64.5708	0.6728
17	10.4891	7.6117	18.3449	62.8181	0.7360
18	10.5102	7.7035	19.8253	61.1782	0.7826
19	10.5314	7.7854	21.2221	59.6452	0.8155
20	10.5613	7.8623	22.5260	58.2122	0.8379
Variance decomposition of ln O_t					
1	2.3399	9.5410	0.0515	1.0278	87.0397
2	2.0852	5.4774	0.0763	1.6057	90.7551
3	2.0315	3.1461	0.3744	1.8523	92.5955
4	2.0556	2.5843	0.7437	2.4767	92.1394
5	2.0776	3.2188	1.1776	3.5712	89.9545
6	2.0449	4.3972	1.6508	5.2813	86.6256
7	1.9355	5.5794	2.1820	7.5958	82.7070
8	1.7676	6.4726	2.7940	10.3633	78.6023
9	1.5856	6.9991	3.5056	13.3207	74.5888
10	1.4340	7.2137	4.3181	16.1877	70.8463
11	1.3372	7.2182	5.2126	18.7454	67.4863
12	1.2935	7.1098	6.1538	20.8756	64.5670
13	1.2835	6.9606	7.0994	22.5548	62.1014
14	1.2836	6.8158	8.0103	23.8232	60.0668
15	1.2761	6.6999	8.8572	24.7504	58.4161
16	1.2536	6.6231	9.6237	25.4103	57.0891
17	1.2181	6.5870	10.3050	25.8673	56.0224
18	1.1770	6.5880	10.9061	26.1721	55.1566
19	1.1392	6.6199	11.4380	26.3622	54.4405
20	1.1115	6.6760	11.9150	26.4647	53.8326

significant structural break in the economy during the sample period. The chow forecast test is more reliable and preferable than graphs [88]. This confirms that the ARDL estimates are reliable and efficient.

The direction of causality between industrialization, electricity consumption, financial development, trade openness and CO_2 emissions was found by applying innovative accounting approach (IAA) rather than the VECM Granger causality method. The VECM Granger causality is suitable to detect a causal relationship between the variables within the sampled period. To determine causality ahead the sample period, the innovative accounting approach is much better. The innovative accounting approach is combination of variance decomposition and impulse response function. The variance decomposition approach indicates the magnitude of the predicted error variance for a series accounted for by innovations from each of the independent variable over different time-horizons beyond the selected time period. It is pointed by Pesaran and Shin [79] that generalized forecast error variance decomposition method shows the proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock effects. Engle and Granger [89] and Ibrahim [90] argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches. The results of variance decomposition approach are described in Table 8. The empirical evidence indicates that a 48.41% portion of CO_2 emissions is contributed by its own innovative shocks and one standard deviation shock in industrialization explains energy pollutants by 5.28% which is minimal.

Electricity consumption contributes to CO_2 emissions by 28.29% due to one standard shock stemming in energy utilization. The share of financial development and trade openness in CO_2 emissions is minimal i.e. 12.07% and 5.93% respectively. Electricity consumption explains industrial development 53.04% due to innovative shocks in electricity consumption. A 24.01% of industrialization is explained by own standard shock. The contribution of CO_2 emissions, financial development and trade openness to industrialization is 4.05%, 2.54% and 16.33% due to one standard shock arises in these series respectively. Electricity consumption is contributed 13.02%, 8.00%, 6.16% and 1.49% by CO_2 emissions, industrialization, financial development and trade openness while rest i.e. 70.78% is contributed by its own sakes.

Similarly, a major contribution (58.21%) in financial development by its own standard shock while contribution by CO_2 emissions, industrialization and trade openness is 10.56%, 7.86% and 0.83% respectively. The contribution in financial development is due to one standard shock in electricity consumption is 22.52%. CO_2 emissions, industrialization, electricity consumption contribute to trade openness by 1.13%, 6.61% and 11.53% respectively. Financial development explains trade openness by 26.36% through one standard deviation shocks stems in financial development. Overall our results indicate that electricity consumption causes CO_2 emissions. Industrialization is also a cause of electricity consumption. The unidirectional causality is running from electricity consumption to financial development and financial development causes trade openness.

The impulse response function (Fig. 3) is alternative to variance decomposition method shows how long and to what extent

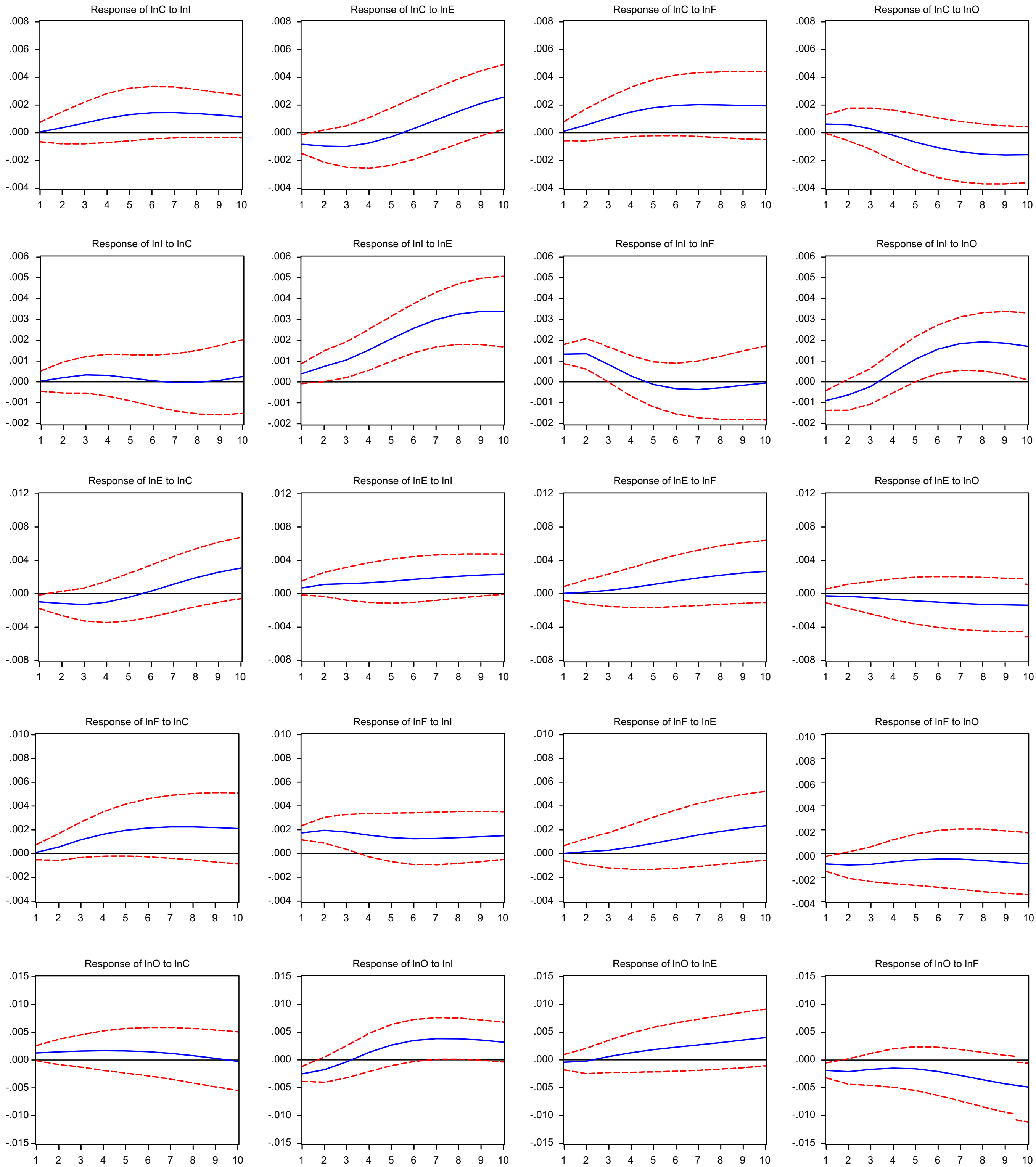

Fig. 3. Impulse response function.

dependent variable reacts to shock stemming in the independent variables. The results indicate that the response in CO_2 emissions due to forecast error stemming in industrialization initially rises, goes to peak and then starts to decline after 8th time horizon. This presents the phenomenon of environmental Kuznets curve between industrialization and CO_2 emissions. The contribution of financial development to CO_2 emissions is positive till 10th time horizon. CO_2 emissions respond negatively but positively after 5th time horizon due to forecast error in electricity consumption. The response in CO_2 emissions is negative after 4th time horizon due to trade openness. Electricity consumption and trade openness contribute positively to industrialization.

The response in electricity consumption is positive due to forecast error arising in industrial and financial development. Financial development responds positively due to shocks in CO_2 emissions, industrialization and electricity consumption but

negatively due to shocks occurring in trade openness. The response in trade openness is inverted U-shaped due to shocks in CO_2 emissions and same for trade openness and industrialization but positive due to forecast error in electricity consumption. Financial development inversely contributes to trade openness.

5. Conclusion and policy implications

This paper deals with empirical investigation of the relationship between CO_2 emissions and industrialization by incorporating electricity consumption, financial development and trade openness as potential determinants of CO_2 emissions in case of Bangladesh. We have applied structural break unit root test and the long run relationship between the variables is investigated by applying the ARDL bounds testing approach to cointegration in the presence of structural break in the series. Causal relationship between CO_2 emissions, industrialization, electricity consumption, financial development and trade openness is scrutinized by using innovative accounting approach.

Our results find that the environmental Kuznets curve exits between industrialization and CO_2 emissions in Bangladesh. Electricity consumption adds in CO_2 emissions. Financial development increases carbon emissions. Trade openness and energy pollutants are positively linked. The causal analysis reveals that electricity consumption causes CO_2 emissions and industrialization. The findings of this paper have an important attention in Bangladesh where the country facing a serious climate change problem. Based on the findings, this paper suggests that Bangladesh government should need to take necessary policy to improve the environmental quality. In order to improve the environmental quality, government should consider the sustainable energy policy that will accelerate the renewable energy production and reduce the energy subsidy in the price level that will mitigate CO_2 emissions. Government should more focus on the clean-energy investment/green investment by adding the implemention of environmental regulation for the dirty industries. In addition regulatory institution provides the financial incentive for clean technology. Financial development causes trade openness and electricity consumption. Hence, sound and developed financial system that can attract investors, boost the stock market and improve the efficiency of economic activities should be encouraged in the country. Sound financial sector also improves the overall trade situation of the country because the cost of doing business is low. Dirty industrialization leads to the increase of the emissions in the country. In Bangladesh, leather, chemical and shipbuilding industries use large amounts of toxic chemicals that has serious negative consequences on the environment. Government should regulate these industries and advise them to adopt environment friendly technology to enhance production of leather, chemical and shipbuilding.

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References

[1] World Bank. World bank development report: development and the next generation. Washington DC, USA: World Bank Press; 2007.

[2] Rahman K. Industrial pollution and control for sustainable development. Training manual on environmental management in Bangladesh. Dhaka: Department of Environment (DoE); 1992.

[3] Islam S, Miah S. Banglapedia (National encyclopedia of Bangladesh). Dhaka: Asiatic Society of Bangladesh; 2003.

[4] Bala SK, Yusuf MA. Corporate environmental reporting in Bangladesh: a study of listed public limited companies. Dhaka Univ J Bus Stud 2003;24:31–45.

[5] Zivot E, Andrews D. Further evidence of great crash, the oil price shock and unit root hypothesis. J Bus Econ Stat 1992;10:251–70.

[6] Soytas U, Sari R, Ewing BT. Energy consumption, income, and carbon emissions in the United States. Ecol Econ 2007;62:482–9.

[7] Kuznets S. Economic growth and income inequality. Am Econ Rev 1955;45: 1–28.

[8] Grossman G. M., Krueger A. B. Environmental impacts of a North American free trade agreement. NBER Working Paper No. 3914/1991. Washington; 1991.

[9] Shafik N. Economic development and environmental quality: an econometric analysis. Oxf Econ Pap 1994;46:757–73.

[10] Dinda S, Coondoo D. Income and emission: a panel data-based cointegration analysis. Ecol Econ 2006;57:167–81.

[11] Heil MT, Selden TM. Panel stationarity with structural breaks: carbon emissions and GDP. Appl Econ Lett 1999;6:223–35.

[12] Friedl B, Getzner M. Determinants of CO_2 emissions in a small open economy. Ecol Econ 2003;45:133–48.

[13] Ang JB. CO2 emissions, energy consumption, and output in France. Energy Policy 2007;35:4772–8.

[14] Ang JB. Economic development, pollutant emissions and energy consumption in Malaysia. J Policy Model 2008;30:271–8.

[15] Saboori B, Sulaiman JB, Mohd S. Economic growth and CO2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Policy 2012;51:184–91.

[16] Dhakal S. Urban energy use and carbon emissions from cities in China and policy implications. Energy Policy 2009;37:4208–19.

[17] Tiwari AK. Energy consumption, CO_2 emissions and economic growth: evidence from India. J Int Bus Econ 2011;112:85–122.

[18] Tiwari AK, Shahbaz M, Hye MQ A. The environmental Kuznets curve and the role of coal consumption in India: cointegration and causality analysis in an open economy. Renew Sustain Energy Rev 2013;18:519–27.

[19] Shiyi C. Energy consumption, CO2 emission and sustainable development in Chinese industry. Econ Res J 2009;4:1–5.

[20] Jalil A, Mahmud S. Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy Policy 2009;37:5167–72.

[21] Zhang XP, Cheng XM. Energy consumption, carbon emissions, and economic growth in China. Ecol Econ 2009;68:2706–12.

[22] Akbostanci E, Türüt-AsIk S, Ipek TG. The relationship between income and environment in Turkey: is there an environmental Kuznets curve? Energy Policy 2009;37:861–7.

[23] Ozturk I, Acaravci A. CO2 emissions, energy consumption and economic growth in Turkey. Renew Sustain Energy Rev 2010;14:3220–5.

[24] Lean HH, Smyth R. CO2 emissions, electricity consumption and output in ASEAN. Appl Energy 2010;87:1858–64.

[25] Narayan PK, Narayan S. Carbon dioxide emissions and economic growth: panel data evidence from developing countries. Energy Policy 2010;38:661–6.

[26] Fodha M, Zaghdoud O. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy 2010;38:1150–6.

[27] Nasir M, Rehman F-U. Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 2011;39:1857–64.

[28] (a) Shahbaz M, Lean HH, Shabbir MS. Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renew Sustain Energy Rev 2012;16:2947–53;
(b) Shahbaz M, Afza T, Zeshan M. Is energy consumption effective to spur economic growth in Pakistan? new evidence from bounds test to level relationships and Granger causality tests Econ Modell 2012;29:2310–9.

[29] Kraft J, Kraft A. On the relationship between energy and GNP. J Energy Dev 1978;3:401–3.

[30] Masih AM M, Masih R. On the temporal causal relationship between energy consumption, real income, and prices: some new evidence from Asian-energy dependent NICs based on a multivariate cointegration/vector error-correction approach. J Policy Model 1997;19:417–40.

[31] Yang HY. A note of the causal relationship between energy and GDP in Taiwan. Energy Econ 2000;22:309–17.

[32] Wolde-Rufael Y. Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy 2006;34:1106–14.

[33] Narayan PK, Singh B. The electricity consumption and GDP nexus for the Fiji Islands. Energy Econ 2007;29:1141–50.

[34] Narayan PK, Narayan S, Prasad A. A structural VAR analysis of electricity consumption and real GDP: evidence from the G7 countries. Energy Policy 2008;36:2765–9.

[35] Akarca AT, Long TV. On the relationship between energy and GNP: a reexamination. J Energy Dev 1980;5:326–31.

[36] Yu ES H, Hwang BK. The relationship between energy and GNP: further results. Energy Econ 1984;6:186–90.

[37] Yu ES H, Jin JC. Cointegration tests of energy consumption, income and employment. Resour Energy 1992;14:259–66.

[38] Stern DI. Energy and economic growth in the USA. Energy Econ 1993;2: 137–50.

[39] Cheng BS. An investigation of cointegration and causality between energy consumption and economic growth. J Energy Dev 1995;21:73–84.

[40] Fatai K, Oxley L, Scrimgeour FG. Modelling the causal relationship between energy consumption and GDP in New Zealand, Australia, India, Indonesia, the Philippines and Thailand. Math Comput Simul 2004;64:431–45.

[41] Yu ESH, Choi JY. The causal relationship between energy and GNP: an international comparison. J Energy Dev 1985;10:249–72.

[42] Erol U, Yu ES H. On the causal relationship between energy and income for industrialized countries. J Energy Dev 1988;13:113–22.
[43] Glasure YU. Energy and national income in Korea: further evidence on the role of omitted variables. Energy Econ 2002;24:355–65.
[44] Oh W, Lee K. Causal relationship between energy consumption and GDP revisited: the case of Korea 1970–1999. Energy Econ 2004;26 (51–9).
[45] Asafu-Adjaye J. The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. Energy Econ 2000;22:615–25.
[46] Narayan PK, Smyth R. Electricity consumption, employment and real income in Australia: evidence from multivariate Granger causality tests. Energy Policy 2005;33:1109–16.
[47] Cheng BS. Causality between energy consumption and economic growth in India: an application of cointegration and error-correction modeling. Indian Econ Rev 1999;34:39–49.
[48] ChangY., Wong, J.F. Poverty, energy and economic growth in Singapore. Working Paper. Department of Economics, National University of Singapore; 2001. p. 1–37.
[49] Soytas U, Sari R. Energy consumption and GDP: causality relationship in G-7 countries and emerging markets. Energy Econ 2003;25:33–7.
[50] Cheng BS, Lai TW. An investigation of co-integration and causality between energy consumption and economic activity in Taiwan. Energy Econ 1997;19:435–44.
[51] Shiu A, Lam PL. Electricity consumption and economic growth in China. Energy Policy 2004;32:47–54.
[52] Masih AM M, Masih R. Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error-correlation modeling techniques. Energy Econ 1996;18:165–83.
[53] Moritomo P, Hope C. The impact of electricity supply on economic growth in Sri Lanka. Energy Econ 2004;26:77–85.
[54] Altinay G, Karagol E. Electricity consumption and economic growth: evidence from Turkey. Energy Econ 2005;27:849–56.
[55] Squalli J. Electricity consumption and economic growth: bounds and causality analyses for OPEC members. Energy Econ 2007;29:1192–205.
[56] Shahbaz M, Lean HH. Does financial development increase energy consumption? the role of industrialization and urbanization in Tunisia Energy Policy 2012;40:473–9.
[57] Shahbaz M, Feridun M. Electricity consumption and economic growth empirical evidence from Pakistan. Qual Quant 2012;46:1583–99.
[58] Lucas G., Wheeler N., Hettige R. The inflexion point of manufacture industries: international trade and environment. World Bank Discussion Paper No. 148/1992. Washington; 1992.
[59] Wyckoff AW, Roop JM. The embodiment of carbon in imports of manufactured products: implications for international agreements on greenhouse gas emissions. Energy Policy 1994;22:187–94.
[60] Nohman A, Antrobus G. Trade and the environmental Kuznets curve: is Southern Africa a pollution heaven. S Afr J Econ 2005;73:803–14.
[61] Halicioglu F. An econometric study of CO2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 2009;37:1156–64.
[62] Anderson H, Favarato G, Atkinson R. Long-term exposure to air pollution and the incidence of asthma: meta-analysis of cohort studies. Air Qual Atmos Health 2010:1–10.
[63] Shahbaz M, Mutascu M, Azim P. Environmental Kuznets curve in Romania and the role of energy consumption. Renew Sustain Energy Rev 2013;18:165–73.
[64] Toda HY, Yamamoto T. Statistical inference in vector autoregressions with possibly integrated processes. J Econom 1995;66:225–50.
[65] Sari R, Soytas U. Are global warming and economic growth compatible? Evidence from five OPEC countries? Appl Energy 2009;86:1887–93.
[66] Tamazian A, Piñeiro J, Vadlamannati KC. Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries? Energy Policy 2009;37:246–53.
[67] Peng S., Sun Z. Energy consumption, structural breaks and economic growth: evidence from China. In: International conference on e-business and e-government (ICEE), 2010, China; 2010.
[68] Mozumder P, Marathe A. Causality relationship between electricity consumption and GDP in Bangladesh. Energy Policy 2007;35:395–402.
[69] Uddin GS, Alam Md M, Murad W. An empirical study on income and energy consumption in Bangladesh. Energy Stud Rev 2011:18 (Article 4).
[70] Paul BP, Uddin GS. Energy and output dynamics in Bangladesh. Energy Econ 2011;33:480–7.
[71] Ahamad MG, Islam AKMN. Electricity consumption and economic growth nexus in Bangladesh: revisited evidences. Energy Policy 2011;39:6145–50.
[72] Ahiduzzamana M, Islam S. Greenhouse gas emission and renewable energy sources for sustainable development in Bangladesh. Renew Sustain Energy Rev 2011;15:4659–66.
[73] Alam MJ, Begum IA, Buysse J, Huylenbroeck GV. Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. Energy Policy 2012;45:217–25.
[74] Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxf Bull Econ Stat 1990;52:169–210.
[75] Amin SB, Ferdaus SS, Porna AK. Causal relationship among energy use, CO_2 emissions and economic growth in Bangladesh: an empirical study. World J Soc Sci 2012;2:273–90.
[76] Hoque A, Clarke A. Greening of industries in Bangladesh: pollution prevention practices. J Clean Prod 2012;30:1–10.
[77] Romero A.M. Comparative study: factors that affect foreign currency reserves in China and India (Honors Projects). Paper 33. United States: Illinois Wesleyan University; 2005.
[78] McDermott J., McMenamin P. Assessing inflation targeting in Latin America with a DSGE Model. Central Bank of Chile Working Papers, No 469, Chile; 2008.
[79] Pesaran MH, Shin Y. An autoregressive distributed-led modeling approach to cointegration analysis. In: Steinar Strom, editor. Econometrics and economic theory in the 20th century. The Ragnar Frisch centennial symposium. Cambridge: Cambridge University Press; 1999.
[80] Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. J Appl Econom 2001;16:289–326.
[81] Narayan PK. The saving and investment nexus for China: evidence from co-integration tests. Appl Econ 2005;37:1979–90.
[82] Shan J. Does financial development 'lead' economic growth? A vector auto-regression appraisal? Appl Econ 2005;37:1353–67.
[83] Baum CF. A review of Stata 8.1 and its time series capabilities. Int J Forecast 2004;20:151–61.
[84] Lütkepohl H. Structural vector autoregressive analysis for cointegrated variables. AstA Adv Stat Anal 2006;90:75–88.
[85] Rahman MH. Financial development and economic growth: a case study of Bangladesh. Bangladesh Dev Stud 2004;30:113–28.
[86] Asian Development Bank, 2009.
[87] Rahman M. Bangladesh's external sector in FY2001: review of performance and emerging concerns. In centre for policy dialogue. Bangladesh facing the challenges of globalisation: a review of Bangladesh's development 2001. Dhaka: University Press Limited; 2002.
[88] Leow YG A. Reexamination of the exports in Malaysia's economic growth: after Asian financial crisis, 1970–2000. Int J Manag Sci 2004;11:79–204.
[89] Engle RF, Granger CW J. Cointegration and error correction representation: estimation and testing. Econometrica 1987;55:251–76.
[90] Ibrahim MH. Sectoral effects of monetary policy: evidence from Malaysia. Asian Econ J 2005;19:83–102.
[91] Shahbaz M, Leitão NC. Portuguese carbon dioxide emissions and economic growth: a time series analysis. Bull Energy Econ 2013;1:1–7.
[92] Shahbaz M, Lean HH. The dynamics of electricity consumption and economic growth: a revisit study of their causality in Pakistan. Energy 2012;39:146–53.
[93] Ghali KH, El-Sakka MI T. Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ 2004;26:225–38.
[94] Zachariadis T, Pashourtidou N. An empirical analysis of electricity consumption in Cyprus. Energy Econ 2007;29:183–98.
[95] Hondroyiannis G, Lolos S, Papapetrou E. Energy consumption and economic growth: assessing the evidence from Greece. Energy Econ 2002;24:319–36.
[96] Jumbe CB L. Cointegration and causality between electricity consumption and GDP: empirical evidence from Malawi. Energy Econ 2004;26:61–8.